Detection of tsunami induced ionospheric perturbation with shipbased GNSS measurements: 2010 Maule tsunami case study

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Outline

1 Introduction

2 The VARION algorithm
   - VARION fundamentals

3 2010 Maule earthquake and tsunami

4 Conclusions and prospects
Travelling Ionospheric Disturbances (TIDs)

(Figure from Occhipinti et al., 2015)
Travelling Ionospheric Disturbances (TIDs)

TIDs related to gravity waves

- atmosphere as **low-pass filter**: only waves with **frequency lower than buoyancy frequency** (about 3.3 mHz at sea level) reach the ionosphere
- **strong amplification** during the upward propagation (density decreasing, momentum conservation)
- ionosphere **perturbations detectable with GNSS**
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VARION fundamentals

**Variometric Approach for Real-time Ionosphere Observation**

**Features**
- derived from VADASE *(real-time ground velocity and displacement)*
- sTEC variation estimation from the observations of a stand-alone GNSS receiver *(single station approach)* in real time
- advantages: no infrastructure, no post-processing, no initialization needed

**Realization**
- designed in 2015 at Sapienza University of Rome
- developed and validated in 2016 in collaboration with the Jet Propulsion Laboratory, Ionospheric and Atmospheric Remote Sensing Group

**Reference**
VARION fundamentals

Methodology

\[ L_{4R}^S(t + 1) - L_{4R}^S(t) = \]

- time single difference
- geometry-free observation

\[ \frac{f_1^2 - f_2^2}{f_2^2} \left[ I_{1R}^S(t + 1) - I_{1R}^S(t) \right] + \Delta m_R^S + \Delta \epsilon_R^S \]

- unknown term, sTEC variation
- noise

Ship-based GNSS receiver application

the receiver motion does not affect the sTEC estimation process
VARION fundamentals

Methodology

- **epoch-to-epoch sTEC variations**

\[
\delta sTEC(t + 1, t) = \frac{f_1^2 f_2^2}{A(f_1^2 - f_2^2)} \left[ L_{4R}^S(t + 1) - L_{4R}^S(t) \right] \tag{1}
\]

note: this is a **total space-time variation**

- **sTEC time series**

\[
\Delta sTEC(t_f, t_0) = \int_{t_0}^{t_f} dTEC(t) \tag{2}
\]
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**Aim of the work**

- Feasibility study on the possibility to use data from ship-based GNSS receiver to detect TIDs
- Application to 2010, $M_W$ 8.8 Chilean (Maule) earthquake and tsunami
2010 Maule earthquake and tsunami

- **two GNSS** receivers installed on a **ship** (green track) moving near Kauai Island in the Hawaiian archipelago
- **one GNSS permanent station** (**KOKB**) placed on Kauai (blue point)
2010 Maule earthquake and tsunami

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Conclusions and perspectives

Summarizing

Ship-based GNSS data for TIDs detection
- if the same satellite is considered, the detected TIDs is the same
- cost-effective tool
- densification of ionosphere monitoring

Outlook

real-time detection of TIDs for enhancing tsunami early warning system
Thanks for your kind attention!

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